HL 20: Focus Session: Young Semiconductor Forum

The young semiconductor forum gives a platform for post-docs at all career stages to present themselves and their scientific ideas. It consists of an oral session with invited talks and immediately afterwards, a poster session, where further participants present a poster about their work and/or scientific vita. With this format, we hope to attract both postdocs and senior researchers and decision makers to join this forum: for postdocs, to give them a platform to present themselves, and for professors, to meet the next generation of scientists.

Organized by Alexander Holleitner and the AGyouLeaP (Susanne Liese, Alexander Schlaich, Doris Reiter, and Christoph Kastl)

Time: Tuesday 9:30–12:15 Location: EW 203

Invited Talk HL 20.1 Tue 9:30 EW 203

Coherent ultrafast exciton dynamics mediated by vibronic couplings — •Antonietta De Sio — Universität Oldenburg

The ultrafast dynamics of non-equilibrium excitations in functional materials and nanostructures, triggered by light-matter interaction, rely on a complex interplay between electronic and nuclear motion. Vibronic couplings may significantly influence the initial energy flow and charge motion following photoexcitation. In-depth understanding of the underlying physics of photoinduced ultrafast phenomena is thus crucial for steering nanoscale energy and charge transport, for the rationale design of efficient new materials and development of quantum technologies. Most of the mechanisms underlying these processes occur on only few 100s-fs timescales, thus demanding methods combining high time resolution and the ability to unravel couplings. Here I would like to give an overview of our most recent results showing how two-dimensional electronic spectroscopy with <10 fs time resolution provides detailed new insight into the ultrafast coherent exciton dynamics in technologically relevant materials, spanning from organic semiconductors to perovskites, and the fundamental role of vibronic couplings in these dynamics[1-2]. Specifically, we recently discovered intermolecular conical intersections in thin films of quadrupolar dyes governing ultrafast energy relaxation within <50 fs. In halide perovskites, we recently unveiled exciton Rabi oscillations driven by coherent phonon fields. Our results also suggest strategies to control ultrafast coherent dynamics in functional materials. [1] De Sio et al, Nature Nano. 16, 63 (2021) [2] Nguyen et al, Nature Comm. 14, 1047 (2023)

Invited Talk HL 20.2 Tue 10:00 EW 203

Merging electron microscopy with advanced photonics — •Armin Feist[1,2], Guanhao Huang[3,4], Germaine Arend[1,2], Yujia Yang[3,4], Jan-Wilke Henke[1,2], Arslan Sajid Raja[3,4], F. Jasmin Kappert[1,2], Rui Ning Wang[3,4], Hugo Lourenço-Martins[1,2], Qiu Zheru[3,4], Junqiu Liu[1,2], Ofer Kfir[3,4], Tobias J. Kippenberg[3,4], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, DE — [2]4th Physical Institute, University of Göttingen, DE — [3]Institute of Physics, EPFL, Lausanne, CH — [4]Center for Quantum Science and Engineering, EPFL, Lausanne, CH

Introducing light optics in state-of-the-art electron microscopes enabled quantum-coherent electron-light interaction [1] and the study of ultrafast nanoscale processes using coherent electron pulses [2]. Recently, high-Q integrated photonics extended these capabilities to continuous electron beams for μeV-resolved electron spectroscopy [3].

Here, we show the coupling of single electrons and photons at a high-Q integrated photonic microresonator [4]. Spontaneous scattering at empty resonator modes creates electron-photon pair states [5], enabling single-particle heralding schemes and noise-suppressed mode imaging. This provides a pathway towards novel hybrid quantum technology with entangled electrons and photons as well as electron-probing with tailored sensitivity for specific material excitations.

[1] A. Feist *et al.*, Nature **521**, 200 (2015). [2] A. Feist *et al.*, Ultramicroscopy **176**, 63 (2017). [3] J.-W. Henke *et al.*, Nature **600**, 653 (2021). [4] A. Feist *et al.*, Science. **377**, 777 (2022). [5] X. Bendaña *et al.*, Nano Lett. **11**, 5099 (2011).

Invited Talk HL 20.3 Tue 10:30 EW 203

Nanotextured Surfaces Based on DNA — •Irina Martynenko and Tim Liedl — Ludwig Maximilian University of Munich (LMU), Department Physics, Geschwister-Scholl-Platz 1, 80539 Munich, Germany

A longstanding goal of material scientists is to fabricate functional materials in which nanoscale objects are precisely positioned on macroscale surfaces. This can be achieved by a combination of bottom-up techniques, such as molecular self-assembly of DNA origami, and top-down lithographic methods. Through DNA origami placement (DOP) on lithographically patterned surfaces a variety of nanoscale components such as organic dyes, proteins or nanoparticles, have already been patterned on large-scale arrays [1, 2]. However, any DOP methods developed so far were limited to two-dimensional DNA origami structures and thus resulted in flat patterns and arrays only. Here we extend DOP to the third dimension through positioning of three-dimensional DNA origami onto nanometer-precise patterns over micro- and even millimeter scales [3]. We demonstrate that our method can produce surfaces nanotextured with three-dimensional hybrid DNA-silica structures with controllable heights up to 50 nm and a feature size down to ~ 6 nm. We believe that the presented strategy can be used for the assembly of a wide range of materials from metals and semiconductors to functional biomolecules arranged in virtually any three-dimensional geometry on large-scale substrates.

[1] R. Kershner, Nat Nanotechnol (2009) [2] A. Gopinath, et al., Nature (2016) [3] I. Martynenko et al., Nat Nanotechnol (2023)

15 min. break

Invited Talk HL 20.4 Tue 11:15 EW 203

Advances in Quantum Light Generation for Quantum Communication — •Tobias Heindel — Institute for Solid State Physics, Technische Universität Berlin, 10623 Berlin, Germany

In this contribution, I will review advances in the generation of flying qubits from solid-state quantum emitters for implementations of quantum communication and networking [1,2]. One spotlight will be on the progress in the on-demand generation of single indistinguishable photons in the telecom C-band exploiting pulsed coherent pumping schemes. Prospects for further improvements are discussed. Moreover, the development of plug-&-play benchtop single-photon quantum key distribution (QKD) systems as well as the transfer to emerging quantum emitter platforms (e.g. 2D quantum materials) are highlighted. Not least, recent experiments towards the generation of multi-partite entangled states are presented, thereby building the bridge from fundamental quantum optics to applications in quantum information.

Many people contributed to this work, including my team members D. A. Vajner, L. Rickert, T. Gao, K. Kaymazlar, N. Kewitz, and M. von Helversen as well as the members of collaborating groups - I express my gratitude to all of them. Financial support by the German Federal Ministry of Education and Research (BMBF) via the Quantum Futur grant "QuSecure" and the BMBF joint project "tubLAN Q.0" as well as by the Einstein Foundation via the Einstein Research Unit "Quantum Devices" is acknowledged.

[1] Vajner et al., Advanced Quantum Technologies 5, 2100116 (2022) [2] Heindel et al., Advances in Optics and Photonics 15, 613 (2023)

Invited Talk HL 20.5 Tue 11:45 EW 203

Membrane external-cavity surface-emitting lasers: A review at the first decade of research — •Hermann Kahle — Institute for Photonic Quantum Systems (PhoQS), Center for Optoelectronics and Photonics Paderborn (CeOPP), and Department of Physics, Paderborn University, 33098 Paderborn, Germany

Membrane external-cavity surface-emitting lasers (MECSELs) have emerged as a derivative of vertical-external-cavity surface-emitting lasers (VECSELs). The pursuit of higher output power, particularly in materials with moderate performance characteristics, has driven the innovation of creating extremely thin amplifier membranes within a nearly ideal thermal environment. These gain membranes, sandwiched

between transparent heat spreaders, containing nothing else but the active region of a VECSEL (no substrate, no monolithically integrated DBR), caught much attention in recent years. Inserting the gain element into a cavity completes the MECSEL, which has already enabled access to laser wavelengths previously unattainable by VECSELs and has facilitated watt-level output power at room temperature. Furthermore, the MECSEL approach fundamentally enables the production of high-power lasers of the highest beam quality whenever it is possible to produce an LED. Beyond that, the membrane approach offers numerous additional advantages.

A comprehensive discussion of these advantages will be provided, as well as a review of the developments that have contributed to the success of MECSELs. The conclusion will give an overview of the most recent findings and a glimpse into future developments in this field.